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SPATIAL DISTRIBUTION OF TROUT AND
CHAR IN THE SPOKANE RIVER BASIN

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THE SPATIAL DISTRIBUTION OF WESTSLOPE
CUTTHROAT IN THE COEUR D'ALENE RIVER
SYSTEM, IDAHO

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**The Spatial Distribution of Westslope Cutthroat Trout
in the Coeur d'Alene River System, Idaho**

Completion Report

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Abstract

Little was known about westslope cutthroat trout *Oncorhynchus clarki lewisi* abundance within third order and smaller tributaries within the Coeur d' Alene River basin. Efforts of this study focused on estimating cutthroat trout abundance and determining those factors influencing abundance for westslope cutthroat trout populations within tributaries of the Coeur d' Alene River basin. We sampled 73 second and third order streams within the Coeur d' Alene River basin, Idaho, during 1994 and 1995 using a stratified random sampling design. A single site within each stream was randomly selected to perform three pass electrofishing, and capture efficiency was estimated using a maximum likelihood estimator. Estimated capture efficiency (\hat{E}) was related to wetted stream width using linear regression ($\hat{E} = -0.053 \cdot WW + 0.855$) to predict capture efficiency for single pass sites. Mean capture efficiency for all multiple pass sites was 68.8%, ranging from 25% to 100%. Single pass catches were adjusted using predicted capture efficiencies to yield density estimates and 95% prediction intervals for all streams. All streams sampled contained westslope cutthroat trout, although the tributaries of the main Coeur d' Alene River had higher densities and biomass ($\bar{x} = 0.152$ fish/m² and $\bar{x} = 1.31$ g/m²) than tributaries of the North Fork of the Coeur d' Alene River ($\bar{x} = 0.038$ fish/m² and $\bar{x} = 0.43$ g/m²). Densities ranged from 0.003 fish/m² to 0.606 fish/m² (mean 95% P.I. of ± 0.197 fish/m²). Differences in density and biomass among streams and among reaches on the main Coeur d' Alene River were both significant ($P < 0.05$). Conversely, differences among reaches on the North Fork were more significant than differences among streams. Westslope cutthroat trout density ($r^2 = 0.14$) and biomass ($r^2 = 0.20$) were weakly, but positively correlated with pool frequency. Logistic regression was a better predictor of cutthroat trout density than was multiple linear regression, but multiple linear regression was a better predictor of cutthroat trout biomass than was logistic regression. Lowest westslope cutthroat trout densities coincided with watersheds that had the most intense forest practices within the past 30

years and the lowest pool frequencies although the statistical significance was low. Pool frequency was negatively correlated to watershed road density ($r^2 = 0.08$). We sampled 11 streams sampled twice during 1994 and concluded that temporal differences in abundance may exist from early summer to early fall. High flow conditions during February 1995 prompted resampling of 30 streams in summer 1995 that were previously sampled in 1994 to determine changes in abundance. Decreases in abundance were detected between 1994 and 1995 for tributaries of the main Coeur d' Alene, but no differences were detected in tributaries of the North Fork. We used nonparametric statistical analysis to determine that streams on the main Coeur d' Alene River did not change in abundance based on ranks although stream ranks on the North Fork were significantly different ($P = 0.622$). During 1994 and 1995 we visually examined shallow calm lateral habitat in 26 first to fifth order streams for recently emerged juvenile cutthroat trout in the Coeur d' Alene River basin and concluded that successful cutthroat trout reproduction was restricted to headwater streams (1st-3rd order) with watershed areas generally $\leq 60 \text{ km}^2$. Using maximum likelihood logistic regression we concluded that the probability of encountering age-0 cutthroat trout in this system decreases as watershed area (WA) increases: $(P_e = (e^{(-0.6719 + WA * 0.0173)}) / (1 + e^{(-0.6719 + WA * 0.0173)}))$. Densities of age-0 cutthroat trout were lower in tributaries of the North Fork of the Coeur d' Alene (mean = 0.003 fish/m^2) than in tributaries of the main Coeur d' Alene River (mean = 0.044 fish/m^2). We used regression and spatial autocorrelation analysis to determine that cutthroat trout density, biomass and length frequency distributions may be spatially structured. The strongest positive ($P < 0.05$) autocorrelation of cutthroat trout density occurred at 1.6 km, and the strongest positive autocorrelation for the interquartile ranges of length frequency distributions occurred at 12.88 km. Our results showed that westslope cutthroat trout abundance is generally within the range others have reported in the literature for westslope cutthroat trout, although the variability of westslope cutthroat trout abundance throughout the Coeur d' Alene River system is generally

greater than other drainages, and a number of biotic and abiotic factors are contributing to this variability in abundance.

Introduction

Historically, westslope cutthroat trout *Oncorhynchus clarki lewisi* were abundant in the Coeur d' Alene River basin (MacLay 1940). Today the combined effects of over fishing, logging activities, road construction, and mineral extraction have reduced numbers of cutthroat within the drainage (Lewynsky 1986; Hunt and Bjornn 1992). Hunt and Bjornn (1992) found an estimated 107 fish/km on the main Coeur d' Alene River and 19 fish/km on the North Fork of the Coeur d' Alene River. However, little is known about the abundance of cutthroat trout within the third order and smaller tributaries within the Coeur d' Alene River basin. Bowler (1974) concluded that over-harvest had reduced westslope cutthroat trout in the Coeur d' Alene River to low levels and recommended more restrictive angling regulations. The Idaho Department of Fish and Game imposed angling regulations which included gear restrictions, minimum size limits (1975), and catch and release on sections of the North Fork (1988) and main Coeur d' Alene (1985) rivers (Hunt and Bjornn 1992). However, cutthroat trout did not respond to special regulations as well as similar streams such as the St. Joe River and Kelly Creek. Lack of favorable cutthroat trout response to special regulations on the Coeur d' Alene River system suggests the potential for habitat related problems, angler noncompliance, or combinations of both.

Cutthroat populations in the Coeur d' Alene River system have three general life history forms (Bowler 1974; Lewynsky 1986). Adfluvial stocks of cutthroat trout that migrated upriver from Coeur d' Alene Lake were historically known to exist in the river basin, but are thought to be restricted to the lower portion of the main stem of the Coeur

d' Alene River (Lewynsky 1986). Juvenile adfluvial cutthroat trout may spend from 2 to 4 years rearing in the main stem of the Coeur d' Alene River before migrating into Coeur d' Alene Lake. Westslope cutthroat trout existing in tributaries and head waters of the Coeur d' Alene River are thought to be resident (Lewynsky 1986). Most of the research to date has focused on the fluvial stock (Bowler 1974; Lewynsky 1986; Hunt and Bjornn 1992). Fluvial cutthroat trout live in the Coeur d' Alene River and larger tributaries and migrate seasonally. Lewynsky (1986) suggests that movements of cutthroat trout in the Coeur d' Alene River system are complex and follow three general patterns:

1) movements towards low velocity runs and pools in the upper and lower reaches in late fall from dispersed spring-summer feeding stations; 2) upstream spring migration and subsequent downstream fall migration; and 3) downstream spring migration and subsequent upstream fall migration.

Conservation biologists consider populations to be spatially structured when habitat is noncontinuously distributed and local populations inhabit patches of habitat surrounded by a matrix of hostile uninhabitable habitat (Hanski and Gilpin 1991; Harrison 1991; Hanski and Gyllenberg 1993). However, populations could also be considered spatially structured if successful spawning locations were not continuously distributed, regardless of the spatial distribution of adults during other times. If reproduction were occurring within the Coeur d' Alene River basin at sites with specific characteristics, then patches may be defined according to those areas where reproduction occurs. However, little information explaining the distribution of spawning locations within the Coeur d' Alene River basin exists, although Lewynsky (1986) observed westslope cutthroat trout

fry in the general location of the headwater streams within the river basin, and from trapping data, concluded that fry emigrate from their natal streams at rates proportional to fry density.

The US Forest Service began collecting stream habitat data during the 1980s and has collected inventory data for most third order and larger streams within the Coeur d' Alene River basin (Fisheries habitat records, US Forest Service, Coeur d' Alene, Idaho, unpublished data). These data include: habitat type (e.g., pool, run, riffle, etc.), habitat type width, length and depth, large woody debris counts, temperatures, substrate composition estimates, and riffle stability indices (RSI; Kappesser 1993).

The relationship between habitat conditions and fish abundance across watersheds has not been investigated for cutthroat trout on the Coeur d' Alene River system, although several authors (Platts 1979; Chisholm and Hubert 1986; Lanka et al. 1987; Fausch 1989; Kozel and Hubert 1989; Bozek and Hubert 1992) suggest a relationship between habitat characteristics, physiographic characteristics, and trout distribution. The quality and quantity of aquatic habitat within the Coeur d' Alene River basin is a product of road construction, timber harvest, and mineral extraction that has occurred since the beginning of the century (Maclay 1940) as well as the physiographic and geomorphic processes that characterize the region today. Kappesser (1993) suggests that forest management activities can influence the timing and peak of a river's hydrograph. Discharge of the North Fork of the Coeur d' Alene River has been recorded at Ennaville, Idaho, since 1939 and averaged $53.9 \text{ m}^3/\text{s}$ (US Geological Survey 1990). Peak flows have occurred during November through February approximately every 2 years since 1939.

During January of 1974 (1727 m³/s) and 1990 (747 m³/s) peak flows were recorded. The amount of bedload material transported on heavily harvested Panhandle Forest streams can approach 80% to 100% of the substrate present (Kappesser 1993). Peak flows can increase bedload scour and channel degradation during the winter months, and may present a risk to westslope cutthroat populations.

Eaglin and Hubert (1993) found that trout standing stock decreased as bank-full width and the density of road culverts increased, and logging and associated road construction increased the rate of sediment delivery to stream channels. Both culvert density and percentage of the drainage basin that was logged were shown to be correlated with cobble embeddedness and fine sediment composition in Wyoming forest streams (Eaglin and Hubert 1993). Others (Murphy et al. 1981; Johnson et al. 1986) suggest that changes in stream trophic structure and increased primary productivity resulting from canopy removal can mask adverse effects of sedimentation. Timber harvest and road construction in the Coeur d' Alene River basin have occurred for over a century (MacLay 1940). Maximum road densities in some portions of the Coeur d' Alene River basin exceed 19 km/km² (US Forest Service, Coeur d' Alene, Idaho, unpublished data).

Stream geomorphology, stream habitat, salmonid abundance, and standing crop are related (Lanka et al. 1987; Kelly et al. 1989; Kozel and Hubert 1989). Lanka et al. (1987) found that geomorphic variables predicted trout standing crop in forested streams as accurately as stream habitat variables. Land type (Modde et al. 1991) and stream valley floor formation (Kelly et al. 1989) have been correlated to habitat type and complexity and patterns of abundance and distribution of salmonids.

Geomorphic characteristics are often important predictors of salmonid abundance (Bozek and Hubert 1992), but the spatial structuring of local populations may be important to fully understand the dynamics of a regional population (Fahrig and Merriam 1994). Rieman and McIntyre (1993) suggested that bull trout *Salvelinus confluentus* have more specific habitat requirements than most other salmonids, and also recognized that migratory corridors that allow dispersal between local patches may be critically important for the conservation of the regional population. Rieman and McIntyre (1993) also suggest that dispersal of bull trout among local populations can recolonize those local populations that have become extinct.

The concept of a spatially dynamic population of subpopulations has been termed a metapopulation (Hanski and Gilpin 1991). According to Hanski and Gilpin (1991), a metapopulation is a system of local populations in which some of the subpopulations occasionally experience extinction, but are recolonized by dispersing individuals from other subpopulations. The term, metapopulation, was first coined by Levins (1969) after formulating a simple model to investigate the dynamics of such a system of local populations (Hanski and Gilpin 1991). Harrison (1991) has expanded the principles of metapopulation dynamics to include almost any population in which dispersal plays an important role, including the biogeographical model first introduced by Brown (1971). Doak and Mills (1994) note that most studies since the early work by Levins (1969) have focused on a modeling and theoretical viewpoint, and that few empirical field studies exist. Nevertheless, conservationists and population biologists have readily accepted and promoted the concept of metapopulations (Hanski and Gilpin

1991; Rieman and McIntyre 1993; Doak and Mills 1994). Perhaps the appeal of the metapopulation concept to conservationists and biologists is that metapopulation structures may strongly influence the probability of persistence of a species in effect, spreading the environmental and demographic stochastic risks of extinction across several small populations rather than a single larger population (Gilpin 1987). These relationships could have some important implications involving the spatial geometric requirements for the species especially when applied towards conservation efforts.

Habitat fragmentation may influence the spatial structuring of westslope cutthroat trout populations within the Coeur d' Alene River system and thus the dynamics and likely persistence. Therefore, habitat fragmentation may have important implications for land management activities within the river basin. If westslope cutthroat trout in the Coeur d' Alene River system were represented by a network of populations connected through dispersal, land management activities that interrupt these processes may alter the probability of persistence within the entire basin. The significance of spatial structuring of cutthroat trout within the Coeur d' Alene River or any system is unknown.

Objectives

1. Estimate cutthroat trout densities for most second and third order tributaries of the Coeur d' Alene River system, and estimate the spatial and temporal variability of cutthroat trout density among and between streams in the Coeur d' Alene River basin;
2. Estimate the spatial distribution of age-0 cutthroat trout in the Coeur d' Alene River system;
3. Estimate which physical habitat and watershed characteristics can be used to predict cutthroat trout density and biomass; and
4. Estimate patterns of spatial structure of cutthroat trout populations within the Coeur d' Alene River system.

Study Area

The Coeur d' Alene River originates on the Pend Oreille divide near the Idaho-Montana border and flows southwesterly approximately 190 km until entering the southeastern end of Coeur d' Alene Lake. The study area covers approximately 2,280 km², encompassing the entire Coeur d' Alene River basin upstream from the confluence of the North Fork of the Coeur d' Alene and the main Coeur d' Alene rivers (Figure 1). Most of the study area is managed by the US Forest Service as part of the Idaho Panhandle National Forests.

Logging and mining activities began impacting the Coeur d' Alene River basin in the mid-1800s (Maclay 1940) and have continued to the present (US Forest Service, Coeur d' Alene, Idaho, unpublished data). Roads parallel most tributary streams within

Coeur d' Alene River Basin

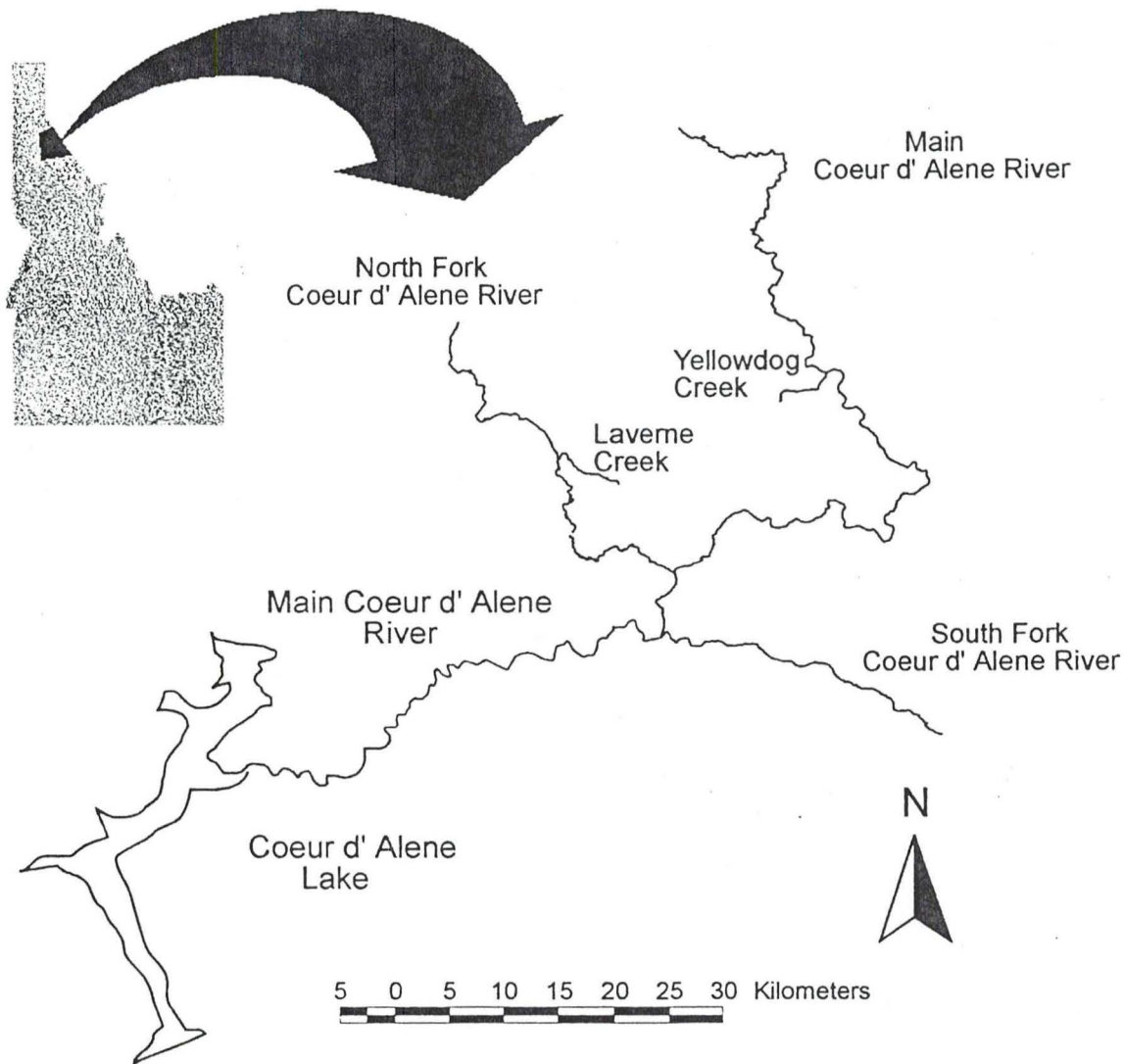


Figure 1. Study area upstream from the confluence of the North Fork of the Coeur d' Alene and main Coeur d' Alene rivers encompassing approximately 2,280 km².

the river basin with the exception of Independence Creek and sections of the upper Coeur d' Alene River. Maximum road densities in some portions of the study area exceed 19 km/km² (US Forest Service, Coeur d' Alene, Idaho, unpublished data). The dominant geology type within the river basin is weathered belt-series rock (Kappesser 1993). Elevations within the study area range from 700 m to 1850 m above sea level.

Cutthroat trout, torrent sculpins *Cottus rhotheus*, shorthead sculpins *Cottus confusus*, and speckled dace *Rhinichthys osculus* are in both the upper and lower portions of the river basin (Hunt and Bjornn 1992). Additionally, rainbow trout *Oncorhynchus mykiss*, brook trout *Salvelinus fontinalis*, mountain whitefish *Prosopium williamsoni*, longnose suckers *Catostomus catostomus*, and northern squawfish *Ptychocheilus oregonensis* occur in the lower portion of the river basin (Hunt and Bjornn 1992). Bull trout were historically found within the Coeur d' Alene River basin (Maclay 1940) but are now believed extinct within the river basin (US Forest Service, Coeur d' Alene, Idaho, unpublished data 1993). Brook trout and rainbow trout are not indigenous to the Coeur d' Alene River basin, but were stocked starting in about 1925 (Maclay 1940), and stocking of rainbow trout continues today.

Chapter 1: Cutthroat Trout Density Estimates

Methods

Sampling

During 1994 and 1995, we conducted electrofishing surveys on 73 streams within the Coeur d' Alene River basin (Figure 2). Nineteen of these streams were tributaries of the North Fork of the Coeur d' Alene and 54 were tributaries of the main Coeur d' Alene River. The length of each stream was measured on a 7.5 minute quadrangle US Geological Survey topological map, and divided into three reaches of equal length. Three 30-m sites from each reach were randomly selected for single pass electrofishing using a Smith Root Model 12 POW backpack electrofisher. One of the nine locations within each stream was randomly selected for three pass electrofishing.

At each sampling location several physical habitat parameters were measured. Wetted stream width and bank-full width (± 0.1 m) were measured at a minimum of five locations at each sampling site. Stream temperatures were recorded (C) using a pocket thermometer at approximately 0800, 1200, and 1600 h. Stream gradient was measured at each location with a hand held clinometer ($\pm 0.5\%$). Visual habitat complexity estimates ranging from 1 (low complexity) to 10 (high complexity) were made for each location sampled. The amount of cover from woody debris, undercut bank, aquatic vegetation, stream depth, substrate, and turbulence contributed to estimates of complexity. To minimize subjectivity, a single investigator determined complexity estimates for all locations. At the beginning of each reach, a 500 ml water sample was taken in the channel

Coeur d' Alene River Basin

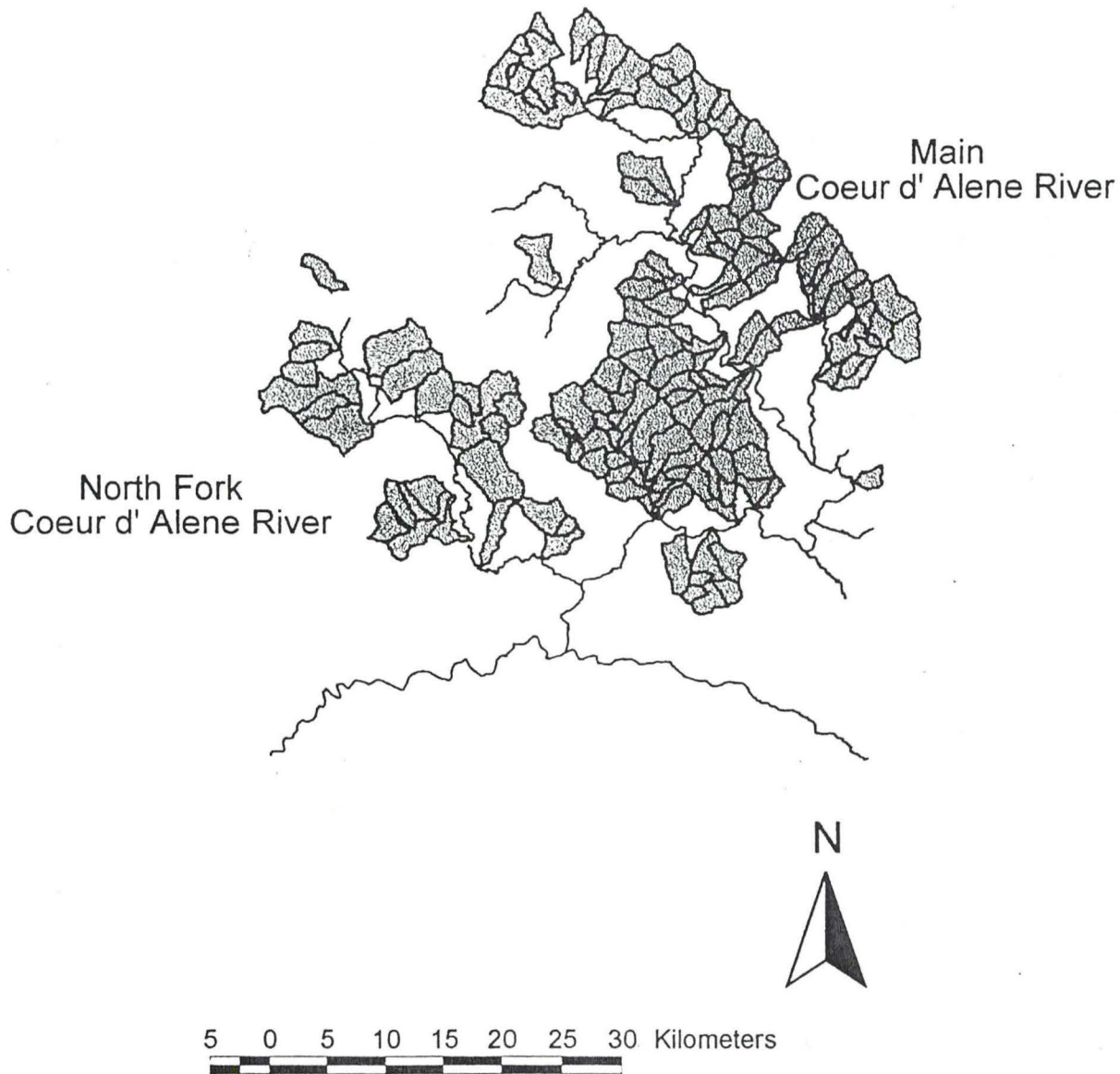


Figure 2. Seventy three watersheds which streams were sampled with a backpack electrofisher during 1994 and 1995.

thalweg, and conductivity was later measured ($\mu S/cm^2$) using a YSI model SCT conductivity meter.

Seven tributaries of the North Fork of the Coeur d' Alene and four tributaries of the main Coeur d' Alene River were sampled twice during the 1994 field season to determine seasonal variation in westslope cutthroat trout distribution. Streams that were sampled prior to August 1, 1994, were classified as early samples, and 11 streams again sampled after September 1, 1994, were classified as late samples.

Thirty streams that were sampled during 1994 were randomly selected for sampling during 1995 to determine if peak flows during the winter of 1994/1995 affected local westslope cutthroat trout populations. Fifteen streams were tributaries of the North Fork of the Coeur d' Alene River and 15 were tributaries of the main Coeur d' Alene River.

Statistical Analyses

Estimates of population abundance and capture efficiency were calculated for all multiple pass locations using the maximum likelihood estimator (Van Deventer and Platts 1983). Capture efficiency estimates from the maximum likelihood estimator (Van Deventer and Platts 1983) were compared to the estimates of stream gradient, conductivity, wetted stream width, bank-full to wetted width ratio, and habitat complexity using multiple linear regression to determine which variables were most useful for predicting capture efficiencies.

The best capture efficiency model was applied to all single pass locations to predict capture efficiencies. A 95% prediction interval was computed using the following formula: $\hat{E} = \pm t_{\alpha/2} \times S_e \sqrt{1 + X'_0 (X'X)^{-1} X_0}$. Where $t_{\alpha/2}$ = the t score for 0.05/2 and $df = n-2$, S_e = standard error of E (predicted capture efficiency), and

$$X = \begin{bmatrix} 1 & x_{11} & \dots & x_{1k} \\ 1 & x_{21} & \dots & x_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \dots & x_{nk} \end{bmatrix}$$

$$X'_0 = [1 \quad x_1 \quad x_2 \dots \quad x_k]$$

Predicted capture efficiency estimates were applied to single pass catches and density estimates and 95% prediction intervals were calculated for each sampling site. Mean densities were calculated by reach and stream.

A student's t-test was used to test if streams on the main and North Fork of the Coeur d' Alene rivers had equal westslope cutthroat trout densities. Analysis of variance (ANOVA) was used to test for density differences ($\alpha < 0.1$) among streams and among reaches. Individual ANOVA procedures were repeated for all streams, all streams on the main Coeur d' Alene River, and for all streams on the North Fork of the Coeur d' Alene River.

A paired t-test was used to test the difference ($\alpha < 0.1$) in westslope cutthroat trout abundance between streams that were sampled early during 1994 and those sampled late during 1994. All young of the year fish (fish < 50 mm FL) were removed from density estimates and the paired t-test was repeated. An analysis of variance ($\alpha < 0.1$)

was also performed to test for differences in densities of cutthroat trout by stream, reach, and time of year. Sampling efficiency for all multiple pass locations was compared to the number of days since the first day of sampling using linear regression to determine if sampling efficiency varied with time throughout the sampling season. To determine if receding water levels throughout the sampling period influenced sampling efficiency, we compared sampling efficiency from all multiple pass locations to corresponding wetted stream width to bank-full width ratios using multiple linear regression ($\alpha < 0.1$).

Sampling during the 1995 field season was initiated by resampling 30 streams that were sampled during 1994 to determine the variability of abundance from year to year. A paired t-test was used to test for significant ($\alpha < 0.1$) differences in abundance between 1994 and 1995. A nonparametric computer simulation was used to test if stream ranks based on density changed significantly ($\alpha < 0.1$) from 1994 to 1995. The simulation randomly assigned density ranks to those streams resampled. The absolute difference of ranks from one simulation to the next was summed, and a histogram of all absolute differences was plotted, approaching a normal distribution after many simulations. The observed absolute difference of ranks from 1994 to 1995 was compared to the randomly generated histogram. The area under the histogram was calculated for the observed absolute difference, approximating a p-value.

Results

Capture efficiency estimates for 71 three pass sites sampled during 1994 and 1995 ranged from 25% to 100% of the cutthroat trout present. The mean for all capture

efficiency estimates was 0.688 ($S^2 = 0.031$ and $n = 71$). Capture efficiency results for 1994 (mean = 0.672, $S^2 = 0.0263$, and $n = 27$) and 1995 (mean = 0.699, $S^2 = 0.0356$, and $n = 43$) were not significantly different ($P > 0.25$).

None of the habitat variables of conductivity, stream gradient, wetted stream width, visual habitat complexity, and wetted width to bank-full width ratios were significantly ($P > 0.1$) related with sampling efficiency ($r^2 = 0.07$, $n = 41$) in a multiple linear regression analysis. However, when the model was reduced to the most significant variable (wetted stream width), the relationship between stream width and capture efficiency was weak but significant ($P = 0.05$, $r^2 = 0.08$). The general linear model for predicting sampling efficiency (E) for a given wetted stream width (WW) was:

$$\hat{E} = -0.045 \times WW + 0.670.$$

Mean catch/m² of cutthroat trout ranged from 0.002 fish/m² to 0.358 fish/m² (mean = 0.073 fish /m², $S^2 = 0.004$). Mean catch of cutthroat trout was higher from streams in the main Coeur d' Alene River drainage (mean = 0.090 fish/m², $S^2 = 0.004$) than from streams in the North Fork of the Coeur d' Alene drainage (mean = 0.028 fish/m², $S^2 = 0.0002$). Predicted densities for all streams sampled during 1994 and 1995 ranged from 0.003 fish/m² to 0.606 fish/m² (Figure 3). Mean predicted density of cutthroat trout for all streams in the Coeur d' Alene River system was 0.125 fish/m² ($S^2 = 0.898$ and mean 95% PI = ± 0.197). Cutthroat trout density estimates were significantly ($P < 0.05$) lower for streams of the North Fork of the Coeur d' Alene River basin (\bar{x} =0.038 fish/m², $n = 20$, $S^2 = 0.167$, and mean 95% PI = ± 0.034) than streams of the

Fish Density

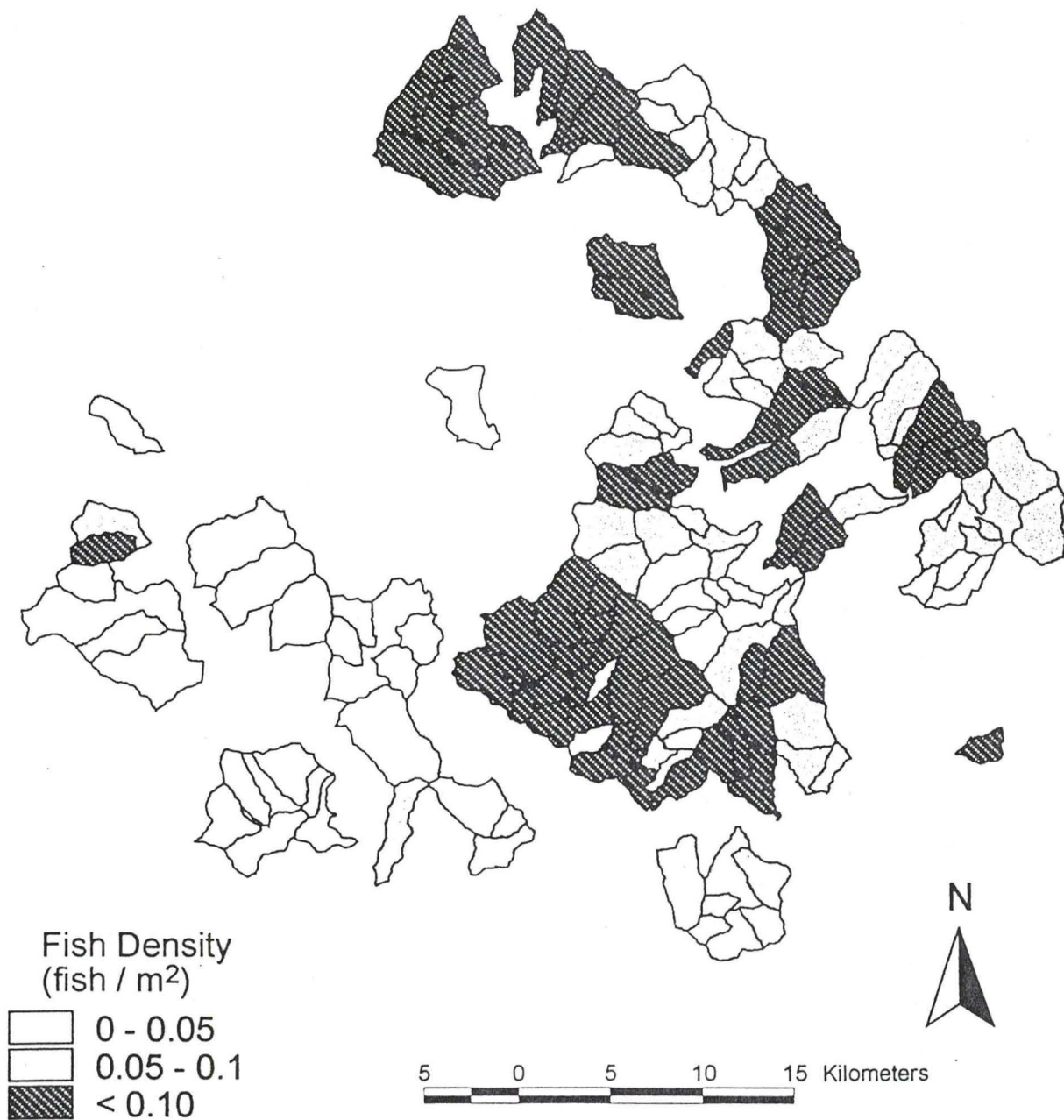


Figure 3. Predicted cutthroat trout densities for 73 streams in the Coeur d' Alene River basin sampled with a backpack electrofisher during 1994 and 1995.

main Coeur d' Alene River basin ($\bar{x}=0.152$ fish/m², $n = 52$, $S^2 = 0.675$, and mean 95% PI = ± 0.224).

Mean cutthroat trout densities were higher ($P < 0.05$) in the upper two reaches than in the lowest reach for all streams sampled (Table 1). The upper most reach of streams of the main Coeur d' Alene River had the highest mean reach density of cutthroat trout (0.179 fish/m²) encountered anywhere in the Coeur d' Alene River basin. Densities were consistently lowest (mean = 0.023 fish/m²) for all reaches sampled on the North Fork of the Coeur d' Alene (Table 1).

Variation of seasonal cutthroat trout abundance within streams was estimated by sampling 11 streams twice during 1994. Cutthroat trout density estimates from streams sampled late during 1994 were significantly higher than cutthroat trout densities from the same streams that were sampled early ($0.001 < P < 0.005$). Results were similar when density estimates were adjusted by removing all young of the year fish (mean difference = 0.05 fish/m²; $S^2 = 0.002$; $P < 0.001$). Observed increases in abundance from early to late sampling periods were significant by stream ($P = 0.0002$), sampling period ($P = 0.0001$), and reach ($P = 0.0266$). No significant relationship was evident when electrofishing efficiency was compared to the number of days since sampling began ($P > 0.20$). Similarly, no relationship could be identified between sampling efficiency and wetted stream width to bank-full width ratio ($P > 0.20$).

Differences in predicted cutthroat trout densities for all streams pooled were significant by stream ($P = 0.0001$) and reach ($P = 0.003$). Reach differences for streams in the North Fork drainage were also significant ($P = 0.009$). However, the stream

Table 1. Mean predicted cutthroat trout density (PD), variance (S^2), and sample size (n) for reaches for all streams, streams of the North Fork and main Coeur d' Alene rivers sampled during 1994 and 1995. Reaches begin at the stream mouth and proceed upstream.

	All stream			North Fork Cd'A			Main Cd'A		
	reaches			reaches			reaches		
	1	2	3	1	2	3	1	2	3
PD	0.107	0.135	0.145	0.023	0.037	0.057	0.127	0.169	0.179
S^2	0.011	0.025	0.015	0.001	0.001	0.001	0.013	0.029	0.016
n	71	70	62	19	18	17	52	51	45

differences for streams tributary to the North Fork were not significant ($P = 0.41$).

Conversely, for streams tributary to the main Coeur d' Alene River, stream and reach differences were significant ($P = 0.013$ and $P = 0.0001$, respectively).

No local extinctions were found during the sampling of the 30 streams that were sampled before and after the 10 year flow event during the winter of 1994/1995. There was insufficient evidence to suggest that the cutthroat trout densities from the 15 streams on the North Fork of the Coeur d' Alene changed ($P > 0.25$ and $1-\beta=0.88$ for $\alpha=0.05$) between 1994 and 1995. The 15 streams on the main Coeur d' Alene River exhibited a significant ($P = 0.01$) decline (44%) of cutthroat trout abundance of 0.076 fish/m^2 from 1994 to 1995. Based on 10,000 random computer simulations, tributaries of the main Coeur d' Alene River that were highest in cutthroat trout abundance in 1994 were also highest in cutthroat trout abundance in 1995 (approximate P value = 0.016) suggesting stream ranks based on cutthroat trout density were unchanged. Conversely, tributaries of the North Fork that were higher in cutthroat trout abundance in 1994 were not higher in cutthroat trout abundance in 1995 (approximate P value = 0.622).

Discussion

Cutthroat trout were present in all streams sampled throughout the Coeur d' Alene River basin, although a substantial gradient in abundance existed across streams. Cutthroat trout abundances were generally higher ($P = 0.001$) for tributaries of the main Coeur d' Alene River than the North Fork of the Coeur d' Alene River, a pattern similar to Hunt and Bjornn's (1992) estimates for the two mainstem rivers using snorkeling.

Although patterns of abundance were similar geographically, our lowest densities for reaches (0.023 fish/m^2) and for streams (0.007 fish/m^2) were both higher than density estimates for the North Fork of the Coeur d' Alene River (mean = 0.002 fish/m^2 ; Hunt and Bjornn 1992). Hunt and Bjornn's (1992) density estimates for the main stem North Fork and main Coeur d' Alene rivers are depressed when compared to similar systems (Bowler 1974; Lewynsky 1986; Hunt and Bjornn 1992).

The range of cutthroat trout densities we observed in second and third order tributaries of both the North Fork and main Coeur d' Alene rivers was within the range observed by other investigators for westslope cutthroat trout. Irving (1987) observed highest densities of ages 1 and older westslope cutthroat trout of 0.3 fish/m^2 from snorkel surveys in the Priest Lake drainage, Idaho. Lukens (1978) reported densities for all age classes of westslope cutthroat trout at approximately 1 fish/m^2 to 2 fish/m^2 , in Wolf Lodge Creek, Idaho. Pratt (1984) reported juvenile westslope cutthroat trout densities in the upper Flathead River basin, Montana, ranging from 0.02 fish/m^2 to 0.60 fish/m^2 . Thurow (1976) reported highest densities of 0.03 fish/m^2 to 0.06 fish/m^2 for age 1 and older westslope cutthroat trout in tributaries of the St. Joe River based on snorkeling. Single pass electrofishing catch data for 23 tributaries of the St. Joe River (B. Rieman, Intermountain Research Station, US Forest Service, Boise, Idaho, unpublished data) indicate that catch rates for tributaries of the St. Joe River and Coeur d' Alene River system are similar. Rieman's (B. Rieman, Intermountain Research Station, US Forest Service, Boise, Idaho, unpublished data) catch of 0.061 fish/m^2 ($S^2 = 0.0011$, $n = 23$) for tributaries of the St. Joe River using a single pass electrofishing technique were lower than

our average catch for all tributaries of the Coeur d' Alene River system and main Coeur d' Alene River (0.073 fish/m² and 0.090 fish/m², respectively), but were higher than our average catch for all tributaries of the North Fork of the Coeur d' Alene River (0.028 fish/m², $S^2 = 0.0002$).

Resident populations of cutthroat trout existing in headwater streams are not believed to migrate (Avertt 1962; Bjornn 1975; Thurow and Bjornn 1978). However, based on repeated sampling of 11 streams during 1994, we concluded that cutthroat trout densities in tributaries of the Coeur d' Alene River system were variable throughout the year with increases in abundance after August. Although cutthroat trout appeared to be seasonally variable, we believe mean seasonal differences (0.05 fish/m²) had little biological meaning when densities were compared across streams. Nine of the eleven streams sampled twice during 1994 had increased catches later in the season. However, seasonal differences were not high enough to change the categorical classification of densities we used to compare cutthroat trout densities across the Coeur d' Alene River basin (Figure 3). Lack of evidence of a change in sampling efficiency throughout the year, coupled with the significance of the stream sampling period and reach differences, suggests that fish migrate into and out of these tributaries. Cutthroat trout movement in the main stem river corridors and larger tributaries of the Coeur d' Alene River system appears to be focused during the early and late portion of the year (Lewynsky 1986). Our research did not address why cutthroat trout in the tributaries of the Coeur d' Alene system migrate. Perhaps, fish are migrating during the late fall into the larger tributaries

and river corridors to over-winter and subsequent upstream spring migration during the spring-summer.

The decrease in cutthroat trout abundance on tributaries of the main Coeur d' Alene River from 1994 to 1995 was likely related to the flow conditions during the winter of 1994/1995. Although we found no evidence of local extinctions within any of the tributaries after the winter flows of 1994/1995, the decrease in abundance of westslope cutthroat trout in streams tributary to the main Coeur d' Alene River suggests that these headwater populations of cutthroat trout are probably subject to stochastic catastrophic events, and local extinctions could occur if the perturbations are of sufficient magnitude. The resampling of streams on the North Fork of the Coeur d' Alene did not result in a significant decline of abundance between 1994 and 1995, possibly because nine sites per stream was not sufficient in detecting changes in streams with low abundance.

Chapter 2: Spatial Distribution of Age-0 Cutthroat Trout in the Coeur d' Alene River Basin

Methods

Sampling

Twenty-six first through fifth order streams were visually sampled for the presence or absence of age-0 westslope cutthroat trout. Sampling was initiated shortly after age-0 fish began appearing in the electrofishing catch (Chapter 1). Observers looked for recently emerged juvenile cutthroat trout in shallow calm lateral habitat commonly inhabited by age-0 cutthroat trout (Kelly et al. 1989) at the lower end of each stream and continued upstream for 200 m. Sampling was terminated after the first effort if age-0 fish were encountered. If no age-0 cutthroat were encountered, sampling continued upstream at 200-m intervals until age-0 fish were located within the stream. A minimum of five wetted stream and bank-full discharge width measurements were taken throughout each 200-m sampling location. Sampling locations were located on 1:24,000 scale US Geological Survey topographic maps, and watershed area and stream gradient were determined for each sampling location. Additionally, 58 third order and smaller streams were sampled using single pass electrofishing after August 1 to determine the density of age-0 cutthroat trout (Chapter 1).

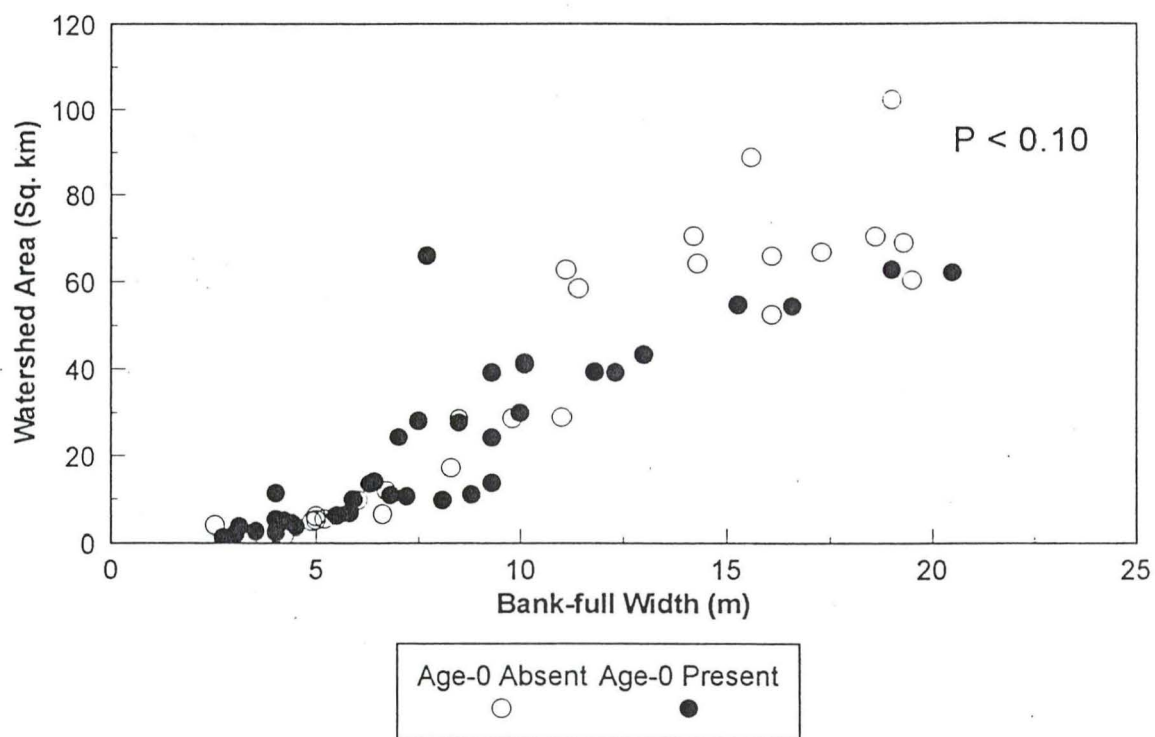
Statistical Analyses

A logistic regression model was fitted to the variables of stream wetted width, bank-full width, and watershed area to infer which characteristics are important for successful westslope cutthroat trout reproduction within the Coeur d' Alene system. A stepwise model selection procedure was used to determine which variables were statistically significant for predicting the presence/absence of cutthroat trout fry. Single pass electrofishing efficiency was adjusted to predict densities of age-0 cutthroat trout based on stream wetted width (Chapter 1).

Results

Age-0 cutthroat trout were rarely encountered in tributaries having watershed areas larger than 60 km² (Figure 4) and were generally restricted to headwater streams (1st - 3rd order). We found no significant ($P = 0.351$) relationship between the presence of age-0 cutthroat trout and bank-full width ($P = 0.831$), wetted stream width ($P = 0.955$), and watershed area ($P = 0.304$). However, when the model was reduced to presence of age-0 cutthroat trout and watershed area ($P = 0.076$) the overall model was significant ($P = 0.075$). The predicted probability of encountering age-0 cutthroat trout (P_e) based on watershed area (WA) was: $P_e = \frac{e^{(-0.6719 + WA \times 0.0173)}}{1 + e^{(-0.6719 + WA \times 0.0173)}}$. The model predicts the probability of encountering age-0 cutthroat trout decreases as watershed area increases (Figure 4).

The mean density of age-0 cutthroat trout using single pass electrofishing for all streams sampled after August 1 was 0.035 fish/m² ($S^2 = 0.002$), and ranged from 0 fish/m²



to 0.176 fish/m². Mean densities of age-0 cutthroat trout were significantly lower ($P < 0.01$) in tributaries of the North Fork of the Coeur d' Alene River (0.003 fish/m², $S^2 = 0.001$, and $n = 13$), than in tributaries of the main Coeur d' Alene River (0.044 fish/m², $S^2 = 0.002$, and $n = 45$).

Discussion

Our visual observations indicate that most successful cutthroat trout reproduction in the Coeur d' Alene River system occurs in third order and smaller tributaries that generally have watershed areas ≤ 60 km². Statistical relationships probably would have been more conclusive if additional visual fry observations had been made in the main stem Coeur d' Alene River. Lewynsky (1986) found similar results within tributaries in the lower Coeur d' Alene River. He believed that age-0 trout occurring in the lower main Coeur d' Alene and North Fork rivers were most likely rainbow trout. Previous work suggests that cutthroat trout abundance for the main Coeur d' Alene River (Hunt and Bjornn 1992) and its tributaries (Chapter 1) was approximately double that in the North Fork of the Coeur d' Alene River. Age-0 cutthroat trout densities were approximately an order of magnitude lower in streams of the North Fork of the Coeur d' Alene basin than in tributaries of the main Coeur d' Alene River. Lewynsky (1986) found higher mean densities of age-0 cutthroat trout densities (0.33 fish/m²) in five tributaries of the main Coeur d' Alene River using snorkeling than we found using electrofishing. We believe that capture efficiency for age-0 cutthroat trout using electrofishing is low, and we were not

surprised to find lower electrofishing estimates compared to snorkel estimates. Although Rieman and Apperson (1989) argue that classification of cutthroat trout abundance is highly subjective, Irving (1987) considered age-0 cutthroat trout densities of 2 fish/m² an indicator of good rearing habitat.

Most tributaries of the North Fork and main Coeur d' Alene rivers have watershed areas less than 60 km², and based on both the visual observations and the single pass electrofishing data, we found evidence of successful cutthroat trout reproduction in most tributaries. Based on the presence of age-0 cutthroat trout in most tributaries of the North Fork and main Coeur d' Alene rivers and their absence in the main river corridors, most tributaries could potentially be described as populations of cutthroat trout, where spawning and rearing of cutthroat trout occurs. Our results are similar to what others (Johnson 1963; Lukens 1978; Shepard et al. 1984; Apperson et al. 1988) have found, indicating that cutthroat spawning and initial rearing were restricted mostly to small tributaries. Lukens (1978) and Johnson (1963) suggested that cutthroat trout used small tributaries for spawning and rearing as an adaptation to avoid variations in spring flows often associated with larger tributaries. Scour, spring flow variation, and presence of spawning gravels could be important factors limiting the distribution of successful cutthroat trout spawning in the Coeur d' Alene River.

Chapter 3: The Spatial Distribution and Relationships Between Cutthroat Trout Abundance, Biomass, and Physical Habitat Conditions

Methods

Sampling

During 1994 and 1995, we conducted electrofishing surveys on 73 streams within the Coeur d' Alene River basin (Figure 2). The length of each stream was measured on a 7.5 minute quadrangle US Geological Survey topological map and divided into three reaches of equal length. Each reach was divided into 30-m potential sampling locations, and three locations from each reach were randomly selected for single pass electrofishing using a Smith Root Model 12 POW backpack electrofisher. One of the nine locations within each stream was randomly selected for estimates of absolute abundance by three pass electrofishing (Chapter 1).

We measured wetted stream width (minimum of five locations at each location) and bank-full discharge widths (± 0.1 m) at each sampling location. Stream temperatures were recorded (C) using a pocket thermometer at approximately 0800, 1200, and 1600 h. Stream gradient was measured at each site with a hand held clinometer ($\pm 0.5\%$). Visual habitat complexity estimates which included cover from woody debris, undercut bank, aquatic vegetation, stream depth, substrate, and turbulence were made ranging from 1 (low complexity) to 10 (high complexity) at each sample location. To minimize the subjectivity of this estimate, a single investigator determined complexity estimates at all

locations. Conductivity was measured ($\mu S/cm^2$) from a 500 ml water sample using a YSI model SCT conductivity meter.

The US Forest Service has been collecting physical habitat data since the early 1980s, including habitat typing inventory (Hankin and Reeves 1988), riffle stability indices (RSI; Kappesser 1993), and large woody debris counts (LWD; woody debris > 30 cm diameter and 1 m long). If physical habitat data existed for streams sampled, it was included in the analyses.

Road densities (km/km^2) in each watershed (ROADS) sampled were calculated using a geographic information system. Records of timber harvest activity were obtained from the US Forest Service to calculate cumulative clearcut area for each watershed. The area of all timber harvest activity that occurred in the past 30 years within each watershed was summed and divided by the total watershed area to estimate total watershed clearcut area (CCUT).

Statistical Analyses

Estimates of population density and capture efficiency were calculated for all three pass sites (Chapter 1) using a maximum likelihood estimator (Van Deventer and Platts 1983). Capture efficiency estimates from the maximum likelihood estimator (Van Deventer and Platts 1983) were compared to stream gradient, conductivity, wetted stream width, bank-full to wetted stream width ratio, and habitat complexity estimates using multiple linear regression to adjust all single pass catches to predict capture efficiencies

and 95% prediction intervals (PI; Chapter 1). For all cutthroat trout captured, fish weight (g) was estimated using the allometric growth equation presented by Rieman and Apperson (1989): $\hat{W} = (4.5 \times 10^{-6})L^{3.14}$. Where \hat{W} = the predicted weight (g), and L = the fork length (mm). We calculated the mean cutthroat trout biomass (g/m²) for each stream (\bar{y}) sampled using the following formula: $\bar{y} = \frac{1}{N} \sum_{i=1}^N N_i \bar{y}_i$. Where N = the total number of sampling locations in the stream, N_i = the number of sampling locations in the i^{th} reach, and \bar{y}_i = the mean cutthroat trout biomass for the i^{th} reach. We calculated mean cutthroat trout density and biomass for all streams that were sampled multiple times within years and between years (Chapter 1) and used these values in the analyses.

Multiple linear regression was used to assess the relationship cutthroat trout density and the physical habitat variables of pool frequency (number of pools/number of all habitat types; POOLS), pool volume (pool habitat volume/volume of all habitat types; PVOL), LWD, RSI (Kappesser 1993), CCUT, ROADS, mean stream elevation (ELEV), stream gradient (GRAD), watershed area (WA), and stream conductivity (CONDUCT). The analysis was repeated using cutthroat trout catch/m² as the dependent variable and independent variables from the final cutthroat density model to assess whether adjustments for capture efficiency (Chapter 1) were confounding results. To determine if results were similar for biomass, we repeated the regression analysis again, using cutthroat trout biomass as the dependent variable.

The mode of cutthroat trout densities for all streams was used to classify streams into the categories of high and low density, and as a response variable for a logistic

regression analyses. The logistic regression model was compared to the multiple linear regression model by comparing the number of concordant and discordant classifications based on each model's predicted values.

The mode of cutthroat trout biomass from all streams was also used to classify streams into the categories of high and low biomass. Cutthroat trout biomass was used as a dependent variable in a logistic regression analyses. Logistic regression results were compared to the multiple linear regression by comparing the number of concordant and discordant classifications made by each model.

A spatially dependent term was introduced as a covariate in the final multiple linear regression and logistic regression models used to predict stream cutthroat trout density and biomass. The mean density of the two nearest streams to every stream (NEXT) was included as a covariate in the multiple regression and logistic regression models. The cutthroat trout abundance logistic and multiple linear regression models containing NEXT were compared by evaluating the number of concordant and discordant classifications based on each model's predicted values. The same comparison was made for the cutthroat trout biomass logistic and multiple linear regression models.

Multiple linear regression was used to assess how ROADS, CCUT, AREA, ELEV, GRAD, and LWD influenced pool frequency. A multivariate analysis of variance ($\alpha < 0.10$; MANOVA) was used to test for simultaneous differences using Wilk's Lambda (Johnson and Wichern 1992) in cutthroat trout abundance, POOLS, ROADS, and CCUT between streams of the North Fork and main Coeur d' Alene rivers. Analysis of variance procedures ($\alpha < 0.10$) were performed to test for differences in cutthroat trout

abundance, POOLS, ROADS, and CCUT between tributaries of the North Fork and main Coeur d' Alene rivers.

A spatial autocorrelation analysis was used to assess the spatial structure of westslope cutthroat trout populations. Spatial autocorrelation statistics detect the presence of interdependence between data at neighboring streams (Sokal and Oden 1978; Cliff and Ord 1973). Moran's I coefficient was used to estimate spatial correlation between densities and length frequency distributions among streams. Values of Moran's I coefficient range from -1 to 1, with positive values of Moran's I suggesting positive correlation and negative values of Moran's I suggesting negative correlation (Sokal and Oden 1978). Interquartile ranges of length frequency distributions from all streams sampled were computed and used as a measure of similarity between length frequency distributions among streams. The Moran's I coefficient was calculated with the following formula:

$$I = \frac{n \sum_{ij} w_{ij} z_i z_j}{W \sum_{i=1}^n z_i^2}$$

Where n = the number of streams sampled, z_i = the mean variable of interest (density or interquartile range of length frequency distributions) for all streams minus the parameter of interest from the i^{th} stream, z_j = the mean parameter of interest (density or interquartile range) for all streams minus the parameter of interest from the j^{th} stream, w_{ij} = the binary connectivity weight between stream $_i$ and stream $_j$, and $W = \sum \sum w_{ij}$. We measured the linear stream corridor distance between each stream and every other stream sampled on

US Geological Survey (1:24,000 scale) topological maps using a digital digitizer to construct a distance matrix for all streams sampled. For all streams that were considered as neighbors the binary connectivity weights (w_{ij}) were assigned a value of 1 and considered connected, for all streams considered as nonneighbors the binary connectivity weights were assigned a value of 0 and considered nonconnected. Values of I were calculated at 1.61, 4.83, 12.88, 20.93, and 41.86 km (1, 3, 8, 13, and 26 miles, respectively). A Moran's I coefficient was calculated for each distance for stream density and interquartile range.

The sampling distribution of I is assumed to be asymptotically normal and can be evaluated as a standard normal deviate to test significance ($\alpha < 0.1$) of values of I . The sampling distribution of I was calculated using the following formula (Cliff and Ord 1973): $\frac{I - E(I)}{\sigma(I)}$. Where $E(I)$ = the expected value of I , and $= -(n-1)^{-1}$, and $\sigma(I)$ is given

by the formula:

$$\sigma(I) = \left[\frac{\left[n \left[(n^2 - 3n + 3) S_1 - n S_2 + 3 W^2 \right] - b_2 \left[(n^2 - n) S_1 - 2n S_2 + 6 W^2 \right] \right]^{\frac{1}{2}}}{(n-1)^3 W^2} \right]^{\frac{1}{2}}$$

$$\text{Where, } S_1 = \frac{1}{2} \sum \sum (w_{ij} + w_{ji})^2,$$

$$S_2 = \sum_{i=1}^n \left(\sum_{j=1}^n w_{ij} + \sum_{i=1}^n w_{ji} \right), \text{ and}$$

$$b_2 = \frac{n \sum_{i=1}^n z_i^4}{\left(\sum_{i=1}^n z_i^2 \right)^2}.$$

Results from the spatial autocorrelation analysis lend evidence to test the spatial independence of cutthroat trout density and length frequency distributions within streams of the Coeur d' Alene River system, and draw inferences about the spatial pattern of local populations.

Results

The mean capture efficiency estimate for cutthroat trout was 0.69 ($S^2 = 0.031$) and ranged from 0.25 to 1.00 for 71 multiple pass sites sampled during 1994 and 1995. Mean capture efficiencies were not significantly different ($P > 0.25$) for 1994 and 1995 of 0.67 ($S^2 = 0.026$, $n = 27$) and 0.70 ($S^2 = 0.036$, $n = 43$), respectively.

Using multiple regression, we found significant relationships between sampling efficiency and wetted stream width (Chapter 1). The general linear model for predicting sampling efficiency (\hat{E}) for a given wetted stream width (m, WW) was:

$$\hat{E} = -0.053 \times WW + 0.855.$$

Predicted densities for all streams sampled during 1994 and 1995 ranged from 0.003 to 0.606 fish/m² (Figure 3). Mean predicted density of cutthroat trout for all streams in the Coeur d' Alene River system was 0.125 fish/m² ($S^2 = 0.898$ and mean 95% PI = ± 0.197). Streams of the North Fork of the Coeur d' Alene River basin ($n = 20$) had lower densities of cutthroat trout (0.038 fish/m², $S^2 = 0.167$ and mean 95% PI = ± 0.034) than streams in the main Coeur d' Alene River basin ($n = 52$, 0.152 fish/m², $S^2 = 0.675$ and mean 95% PI = ± 0.224). Results for mean catch and biomass were similar to those for density between river systems (Table 2). Biomass and mean catch were lowest for

Table 2. Mean cutthroat trout biomass densities (g/m^2), catch/ m^2 , variance, and sample size for all streams, streams of the North Fork, and streams of the main Coeur d' Alene rivers.

Streams	g/m^2	S^2	Catch/ m^2	S^2	n
All streams	1.07	0.597	0.073	0.004	70
North Fork	0.43	0.044	0.028	0.001	19
Main Cd' A	1.31	0.596	0.090	0.004	51

tributaries of the North Fork of the Coeur d' Alene, and highest for tributaries of the main Coeur d' Alene River (Table 2).

We found no significant relationship ($P = 0.460$) between predicted cutthroat trout density and the independent variables of POOLS, PVOL, RSI, CCUT, ROADS, LWD, CONDUCT, AREA, ELEV, and GRAD ($r^2 = 0.49$; $n = 23$; Appendix Table 1). Missing observations of two nonsignificant independent variables of LWD ($P = 0.571$) and RSI ($P = 0.524$) limited the total number of observations in the original model ($n = 23$). After dropping LWD and RSI from the model POOLS, ROADS, and CCUT were the only significant ($P < 0.1$) variables, although the following overall model was not significant ($P = 0.153$; Appendix Table 2). When the model for predicted westslope cutthroat trout abundance (CT) was reduced to POOLS, ROADS, and CCUT the model ($P = 0.015$) and variable POOLS ($P = 0.009$) were significant ($r^2 = 0.219$; $n = 46$; Appendix Table 3): $CT = 0.006*POOLS - 0.019*CCUT + 0.011*ROADS - 0.03$. The model including POOLS, CCUT, and ROADS suggested a significant positive relationship between ROADS and cutthroat trout density, but the model including the dependent variable of cutthroat trout density and independent variable of ROADS was not significant ($P = 0.380$). A model including only POOLS ($P = 0.007$) as the independent variable was significant overall ($P = 0.007$; $r^2 = 0.141$; $n = 49$): $CT = 0.01*POOLS - 0.003$.

Results from the multiple linear regression using catch/m² (CATCH; $P = 0.015$; $r^2 = 0.222$; $n = 44$; Appendix Table 4) and biomass (BMASS; $P = 0.026$; $r^2 = 0.204$, $n = 44$;

Appendix Table 5) were similar to those results using mean cutthroat trout density and yielded the following models:

$$\text{CATCH} = 0.003*\text{POOLS} - 0.010*\text{CCUT} + 0.009*\text{ROADS} - 0.026, \text{ and}$$

$$\text{BMASS} = 0.039*\text{POOLS} - 0.057*\text{CCUT} + 0.077*\text{ROADS} - 0.164.$$

The mode of predicted westslope cutthroat trout density for all streams was approximately 0.1 fish/m², and was used as a boundary to categorize high (> 0.10 fish/m²) and low (< 0.10 fish/m²) cutthroat trout abundance. The logistic regression model (P = 0.252) classified 67% of the observations correctly, and the multiple linear regression model (P = 0.022) classified 55% of the predicted values correctly. The logistic regression model failed to show any significant relationships between cutthroat trout density and the independent variables of POOLS, CCUT, and ROADS (Appendix Table 6).

The mode of predicted cutthroat trout biomass for all streams was approximately 0.7 g/m², and was used as a boundary to categorize high (> 0.7 fish/m²) and low (< 0.7 g/m²) cutthroat trout biomass. The logistic regression approach to model cutthroat trout biomass failed to show any significant relationships (P > 0.1) between the response variable and the independent variables of POOLS, CCUT, and ROADS (Appendix Table 7). Overall, the logistic regression model was not significant (P = 0.914), although the model correctly classified 61% of the observations into the appropriate biomass categories. In comparison, a multiple linear regression model (P = 0.0263; r² = 0.204; Appendix Table 3) correctly classified 77% of the predicted biomass estimates.

The multiple linear regression model which included the mean density of the two nearest streams (NEXT) as a covariate suggests the importance of spatial structuring of cutthroat trout densities throughout the Coeur d' Alene River basin. When NEXT was included as a covariate in the multiple linear regression cutthroat trout abundance model ($P = 0.02$; $r^2 = 0.212$; Appendix Table 3), the coefficient of determination increased to 0.339. The parameter estimates of POOLS, ROADS, and CCUT remained relatively constant from the original model to the new model. However, the level of significance of each variable (Appendix Table 8) and overall model significance ($P = 0.0002$) increased in the following model used to predict cutthroat trout density (CT):

$$CT = 0.459 * NEXT + 0.006 * POOLS - 0.019 * CCUT + 0.015 * ROADS - 0.119.$$

Results were similar for the multiple linear regression model used to predict cutthroat trout biomass (BMASS; $P = 0.026$; $r^2 = 0.204$; Appendix Table 4) when the variable NEXT was included in the following model ($P = 0.0002$; $r^2 = 0.427$; Appendix Table 9):

$$BMASS = 4.047 * NEXT + 0.040 * POOLS - 0.048 * CCUT + 0.104 * ROADS - 0.930.$$

The introduction of the variable NEXT to the logistic regression model used to predict high and low cutthroat density increased the overall model level of significance ($P = 0.017$; Appendix Table 10) from the original model ($P = 0.252$). Classification success of the new model increased from 67% to 76%. The introduction of the variable NEXT into the logistic regression model used to predict cutthroat trout biomass also increased the overall model significance ($P = 0.022$; Appendix Table 11) from the original model ($P = 0.914$). However, NEXT was the only significant ($P = 0.004$) variable in the new

model (Appendix Table 11). The addition of the spatially dependent variable improved biomass classifications from 61% to 85%.

The logistic regression model including NEXT classified cutthroat trout density better than the multiple linear regression model (76% and 59%, respectively) using the same variables of NEXT, POOLS, CCUT, and ROADS. The models for cutthroat trout biomass showed similar results. The classification success from the logistic regression increased to 85% from 78% with the multiple linear regression.

Multiple linear regression revealed no significant ($P > 0.1$) relationships between POOLS and ROADS ($P = 0.611$), LWD ($P = 0.984$), AREA ($P = 0.178$), ELEV ($P = 0.216$), GRAD ($P = 0.905$), and CCUT ($P = 0.332$). Missing LWD count observations limited the model ($n = 27$), and therefore, this nonsignificant variable was dropped, and the analysis repeated, although all variables and the overall model remained nonsignificant (Appendix Table 12). The best general linear model for predicting pool frequency was: $\text{POOLS} = -0.702 * \text{ROADS} + 32.61$ ($P = 0.057$; $r^2 = 0.08$).

We found a significant difference ($P = 0.0217$ using Wilk's Lambda) between cutthroat density, POOLS, ROADS, and CCUT between streams of the North Fork of the Coeur d' Alene and the main Coeur d' Alene rivers. Tributaries of the North Fork had significantly ($P = 0.009$; Figure 3) lower cutthroat trout abundance but not significantly ($P = 0.150$; Figure 5) lower pool frequencies than tributaries of the main Coeur d' Alene River. Watersheds on the North Fork of the Coeur d' Alene River had significantly higher ROADS ($P = 0.067$) and higher CCUT ($P = 0.089$).

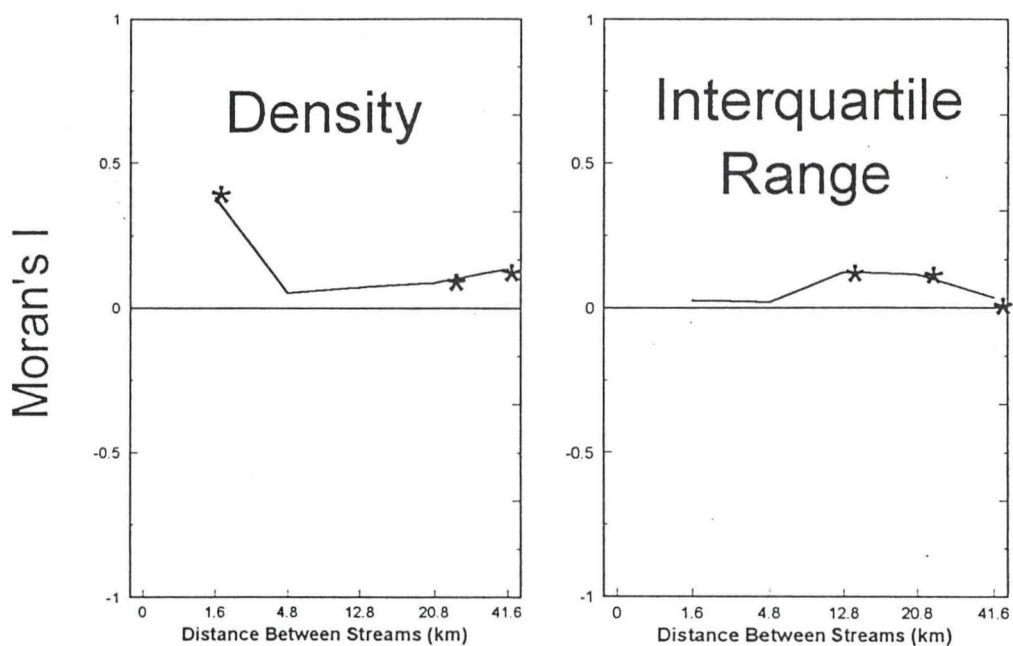


Figure 5. Correlograms for the spatial autocorrelation analysis of density and interquartile range of cutthroat trout length frequency distributions for streams in the Coeur d' Alene River basin sampled during 1994 and 1995 (*Significant $P < 0.05$)

The strongest positive spatial correlation for density of cutthroat trout ($I = 0.382$) occurred when those streams located within 1.61 km (1 mile) of each other were considered neighbors ($P < 0.05$). Significant ($P < 0.05$) spatial correlation also occurred for streams located within 20.93 km (13 miles; $I = 0.087$; Figure 5) and 41.86 km (26 miles; $I = 0.136$; Figure 5).

Similarly, significant positive spatial correlation for the parameter of interquartile range of length frequency distributions occurred when streams located within 1.61, 12.88, 20.93, and 41.86 km (1, 8, 13, and 26 miles, respectively) were considered neighbors ($P < 0.05$). Strongest significant ($P < 0.05$) positive spatial correlation for interquartile range (Figure 5; $I = 0.124$) occurred when streams located 12.88 km or less from each other were considered neighbors.

Discussion

Many factors have been related to trout abundance in streams. However, the scale of most studies relating trout abundance to habitat variables has focused on in-stream effects rather than among-stream effects as this study did. Pool habitat has been identified as critical habitat for westslope cutthroat trout (Irving 1987; Pratt 1984). We found that pool frequency was significantly but weakly ($r^2 = 0.14$) correlated to cutthroat trout abundance. However, Lanka et al. (1987) found a link between geomorphological and reach habitat variables, and indicated that geomorphic variables could predict trout standing crops as accurately as physical habitat variables. Kozel and Hubert (1989) suggest that stream size and reach gradient are two dominant geomorphic factors that

more strongly influence stream habitat and trout standing crop in streams minimally altered by man. These variables were not significant in the Coeur d' Alene River basin, possibly because of the long history of land development activities in the basin (MacLay 1940). Some watersheds sampled in the Coeur d' Alene River had more than 60% of area clearcut in the last 30 years, road densities up to 9 km/km², and some smaller watersheds nested within larger watersheds had road densities exceeding 19 km/km².

Effects of logging on trout abundance and growth can be conflicting (Johnson et al. 1986). Few studies have addressed which component of logging, either the actual canopy removal or the associated road construction, has the largest indirect impact on salmonids. Eaglin and Hubert (1993) found that both culvert density and the percent ground surface logged were both positively correlated to cobble embeddedness and fine sediment, whereas trout standing crop was negatively related to culvert density. However, we found no evidence of a significant negative relationship between watershed road density and cutthroat trout density or biomass within the Coeur d' Alene River system using either multiple linear regression or logistic regression. Murphy et al. (1981) concluded that effects of sedimentation could be offset by positive changes in trophic status that increased primary productivity and subsequently increased abundance of salmonids. However, we believe that the erosive nature of the weathered belt-type geology and subsequent loss of pool habitat was probably not offset by increases in cutthroat trout productivity in tributaries of the Coeur d' Alene basin. Johnson et al. (1986) found similar results and concluded that any positive effects of canopy removal from clearcuts was offset by a reduction in critical winter-rearing habitat for juvenile steelhead.

The importance of pool habitat by cutthroat trout is not clearly understood, although many investigators have indicated the importance of pools for juvenile cutthroat trout rearing habitat (Pratt 1984; Irving 1987; Wilson et al. 1987). Likewise, factors which influence pool frequency on the Coeur d' Alene River basin are also poorly understood. We were able to account for only 8% of the variation in pool frequency. Peak runoff flows on the Coeur d' Alene River system probably also influence pool habitat. Peak flows usually occur in April and May, however, channel forming flows resulting from rain on snow events have occurred during November through February approximately every 2 years (US Geological Survey 1990). The amount of bedload transported during channel forming flows in the Coeur d' Alene River basin can be as much as 80% to 100% of the substrate present (Kappesser 1993). Kappesser (1993) suggests that bedload in the Coeur d' Alene River system tends to deposit in low velocity locations, such as pools. Under conditions such as these, pool habitat probably influences cutthroat trout abundance in the Coeur d' Alene River system. Although not known, the quality of pool habitat in the Coeur d' Alene River system may be important for the over-wintering of westslope cutthroat trout.

Angler harvest has been shown to be another factor influencing cutthroat trout abundance in the main stem Coeur d' Alene River (Bowler 1974; Lewynsky 1986). During field work, we seldom observed fishing in second and third order tributaries due to dense brush cover that occurs adjacent to most tributaries that can interfere with fishing. Therefore, we believe fishing has little direct effect on abundance of populations in second and third order tributaries in the Coeur d' Alene basin.

Cutthroat trout abundance was generally higher in tributaries of both river systems in the upper reaches (Chapter 1). We suspect that differences in abundance between reaches within streams was most likely related to habitat conditions between reaches, although the relationship between reach habitat conditions and cutthroat trout abundance was not evaluated. We observed increased gradient and changes in channel morphology in the upper reaches and believe these geomorphological changes influenced habitat stability and fish abundance.

Lowest cutthroat trout densities generally coincided with conditions on the North Fork of the Coeur d' Alene River where watershed clearcut area and road densities were significantly higher than watersheds within the main Coeur d' Alene River. However, multiple linear regression relating cutthroat trout density to pool frequency, pool volume, riffle stability indices, watershed clearcut area, large woody debris counts, stream conductivity, watershed area, and watershed road density revealed no significant relationships. After the model was reduced to pool frequency a significant relationship was detected.

Missing habitat data observations, cutthroat trout density and habitat variability between years, and sampling time constraints probably all contributed to weak statistical relationships. Missing observations of large woody debris counts and riffle stability indices in the original model limited the number of observations by approximately two thirds, and pool frequency data were missing for approximately 25% of all observations. Many of the missing pool frequency observations occurred in the upper Coeur d' Alene River where densities were generally high and watershed clearcut area and road densities

were low. From field work, we observed that tributaries in this region had higher pool frequencies and, therefore, missing pool frequency observations probably influenced attempts to model cutthroat trout density as a function of pool frequency and pool frequency as a function of watershed road density. Electrofishing results from 1994 and 1995 were used to model cutthroat trout abundance. Winter flow patterns were different between 1994 and 1995 and probably responsible for differences in abundance between years (Chapter 1). Attempts to account for temporal differences in cutthroat trout abundance in modeling efforts may have further strengthened statistical relationships. Additionally, habitat variability may have limited results. Lider (US Forest Service, Coeur d' Alene, Idaho, unpublished data) concluded that fisheries habitat is variable between years for some streams in the Coeur d' Alene River system. Habitat data included in our analyses were collected from 1991 through 1995 and may not have accurately reflected habitat conditions at the time of electrofishing. Another limitation of sampling as many tributaries as time permits is relying on single pass electrofishing to estimate abundance. However, we are confident in the density estimates based on our mean capture efficiency (0.69), relatively tight 95% prediction intervals, and intensive random sampling techniques. Additional support for our belief is that using catch as a dependent variable in the models did not change the significance of the independent variables.

The logistic regression model was superior at classifying high and low cutthroat trout densities than was the multiple linear regression model, using the independent variables of pool frequency, watershed clearcut area, and watershed road density. Prairie

(1996) suggests that regression models with $r^2 \leq 0.65$ are unable to statistically distinguish between two classes. Conversely, the multiple linear regression model was a better predictor of cutthroat trout biomass than was the logistic regression. However, in both instances overall model significance and variable significance decreased from the multiple linear regression model to the logistic regression model, suggesting that perhaps two categories of classification in the logistic regression provided too broad of range to adequately discern significant relationships.

Results from the spatial autocorrelation analyses of cutthroat trout density suggest the possibility that local populations of cutthroat trout in the Coeur d' Alene River system are spatially structured. We found that cutthroat trout densities throughout the Coeur d' Alene River system were correlated with a spatial pattern. Streams close to each other tend to have similar densities of cutthroat trout than do streams further apart. This relationship suggests that observations of westslope cutthroat trout density within streams of the Coeur d' Alene River system are not independent. However, a similar pattern for cutthroat trout length frequency distributions between streams was not observed. Spatial correlation for length frequencies were weak ($I \leq 0.124$) at all distances. Spatial autocorrelation can result from synchronous environmental conditions, community processes, or combinations of both (Legendre 1993). At this point, we cannot discern which of these phenomena are causing the positive spatial autocorrelation of cutthroat trout density within the Coeur d' Alene River system.

The ability of a species to disperse is a prerequisite for classification as a metapopulation (Gilpin 1987; Hanski and Gilpin 1991). The early/late sampling of tributaries during the 1994 field season (Chapter 1) and Lewynsky's (1986) conclusions suggest cutthroat trout in the Coeur d' Alene River system may exhibit complex movement patterns during the spring and fall. However, this is insufficient evidence alone to suggest classifying cutthroat trout in the Coeur d' Alene River system as a metapopulation.

If dispersal were an important factor in the dynamics of local populations of cutthroat trout in the Coeur d' Alene River system, then we would have expected to see the strongest spatial autocorrelation for sizes and density correspond to the dispersal distance of cutthroat trout. Dispersal of animals has been classified into environmentally (short distance) and innately (long distance) driven dispersal (Hansson 1991). If cutthroat trout dispersal were environmentally driven in the Coeur d' Alene system, then we expected to see patches in close proximity displaying similar characteristics (such as similar length frequency distributions) that would indicate dispersal between patches in close proximity. Our analysis suggest that streams in close proximity did not exhibit similar length frequency distributions, with the closest (and strongest) significant spatial autocorrelation for interquartile range of length frequency distributions occurred at 12.88 km. However, low catches in some tributaries may have influenced our results. The strongest significant positive spatial autocorrelation for density occurred for streams located within 1.6 km of each other, which may be a result of environmental correlation and not effects of dispersing individuals. However, additional autocorrelation analyses on

the residuals from the regression models with and without the spatially dependent term is required to definitively establish factors influencing the spatial pattern of cutthroat trout densities.

Little is known about the genetic composition of cutthroat trout on the Coeur d' Alene River system. Allendorf and Leary (1988) note that allelic variation for typical westslope cutthroat populations is composed of alleles that have a relatively narrow geographic distribution, and typically occur in high frequency in local populations, a situation that would not typically be consistent with a metapopulation structure (Gilpin 1991). However, habitat fragmentation, caused by human development, can create a metapopulation from a formerly continuously distributed species, such as the cutthroat trout (Gilpin 1991).

Most classical metapopulations consist of a system of local populations in which some subpopulations occasionally experience extinction and refounding (Hanski and Gilpin 1991; and Gilpin 1987). We found no evidence of local extinctions of resident populations of cutthroat trout in the Coeur d' Alene River system therefore, resident cutthroat trout in the Coeur d' Alene River system are probably not exhibiting the classical metapopulation structure (Hanski and Gilpin 1991) with common extinctions and refounding. Based on the sampling of streams after the approximate 10-year flow event during the winter of 1994/1995 (Chapter 1), we concluded that either local extinctions within the system are only caused by relatively infrequent large stochastic catastrophic events, or that refounding of local populations occurs rapidly after extinction.

Lack of local extinctions in populations does not necessarily mean that spatial structuring is unimportant. Harrison (1991) has suggested that the population dynamics of several terrestrial species are dependent upon dispersal between local populations even though local extinctions were not common. Few have suggested the importance of dispersal and spatial structuring for salmonid populations. Rieman and McIntyre (1993) suggested that bull trout have more specific habitat requirements than most other salmonids, and they also recognized that migratory corridors that allow dispersal between local patches may be critically important for the conservation of the regional population. Perhaps dispersal between local patches of noncontinuously distributed cutthroat trout spawning habitat (Chapter 2) is important in the Coeur d' Alene River system.

Regardless of the importance of dispersal to the regional and local populations of cutthroat trout within the Coeur d' Alene River system, the spatial structuring of densities appears to violate the assumption of independent observations of classical statistics because values of density in any one stream can be partially predicted by the values for fish in neighboring streams; in other words, new observations do not bring with them one full degree of freedom (Legendre 1993). The violation of independence is demonstrated by the multiple linear and logistic regression models using the spatially dependent term which more accurately predicted cutthroat trout abundance and biomass than those that did not contain the spatially dependent term. This implies that either some environmentally correlated factor which was unaccounted for in the statistical analysis, or effects are caused by dispersing individuals. Legendre (1993) notes that most ecological phenomena exhibit environmental patchiness often caused by geomorphological

processes. Unless investigators can quantify all ecological components influencing species abundance, it may be necessary to revise theories and models to include assumptions about spatial structuring.

Summary

1. We estimated cutthroat trout densities using single pass electrofishing for 73 second and third order tributaries in the Coeur d' Alene River basin during 1994 and 1995.
2. Cutthroat trout were present in every stream sampled in the Coeur d' Alene River system, but sampling in 1995 after a 10 year flow event indicated that westslope cutthroat trout abundances in streams tributary to the main Coeur d' Alene River were significantly lower than the previous year.
3. Mean densities of cutthroat trout were significantly higher in tributaries of the main Coeur d' Alene River than in the North Fork of the Coeur d' Alene, although a substantial gradient of densities existed across streams. Lowest densities of streams tributary to the North Fork of the Coeur d' Alene River generally coincided with areas of the highest watershed road density and clearcut area although statistical relationships were weak.
4. The presence of age-0 cutthroat trout was negatively correlated to watershed area. Cutthroat trout were generally restricted to headwater streams with watershed areas $\leq 60 \text{ km}^2$.
5. Pool frequency was significantly but weakly correlated ($r^2 = 0.14$) to cutthroat trout density. Possible reasons for the weak relationship were: missing pool frequency observations in streams located in the upper Coeur d' Alene basin where cutthroat trout densities were generally high, cutthroat trout variability between and within years, pool frequency data used in the analyses did not accurately reflect conditions when electrofishing occurred because pool frequency data collection and electrofishing

occurred at separate times, and the time constraints of this project which required single pass electrofishing to estimate densities.

6. Cutthroat trout abundance was variable between June and September 1994, suggesting that these westslope cutthroat trout populations may exhibit movements.
7. Results from the spatial autocorrelation and regression analyses suggest spatial structuring of cutthroat trout densities across the Coeur d' Alene River basin.

However, a similar pattern was not evident for cutthroat trout length frequency distributions. The reasons for the spatial correlation of cutthroat trout densities are unknown but could be related to community processes or environmental factors.

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Appendix Table 1. Probabilities testing the null hypothesis parameter slope = 0 resulting from a multiple regression ($r^2 = 0.491$) of the dependent variable cutthroat density and the independent variables of pool frequency (POOLS), pool volume (PVOL), watershed clearcut area (CCUT), riffle stability indices (RSI), watershed road density (ROADS), large woody debris counts (LWD), mean stream conductivity (CONDUCT), watershed area (AREA), mean stream elevation (ELEV), and stream gradient (GRAD).

Variable	Parameter Estimate	p-value
POOLS	0.005	0.414
PVOL	0.005	0.929
CCUT	-0.070	0.040
RSI	0.003	0.524
ROADS	0.045	0.083
LWD	-0.0004	0.571
CONDUCT	-0.0009	0.650
AREA	0.00001	0.743
ELEV	0.0001	0.694
GRAD	0.0001	0.887

Appendix Table 2. Probabilities testing the null hypothesis parameter slope = 0 resulting from a multiple regression ($r^2 = 0.491$) of the dependent variable cutthroat density and the independent variables of pool frequency (POOLS), pool volume (PVOL), watershed clearcut area (CCUT), watershed road density (ROADS), mean stream conductivity (CONDUCT), watershed area (AREA), mean stream elevation (ELEV), and stream gradient (GRAD).

Variable	Parameter Estimate	p-value
POOLS	0.005	0.041
PVOL	0.0001	0.952
CCUT	-0.070	0.040
ROADS	0.022	0.027
CONDUCT	-0.0003	0.636
AREA	0.00001	0.683
ELEV	0.00004	0.480
GRAD	0.0001	0.591

Appendix Table 3. Probabilities testing the null hypothesis parameter slope = 0 resulting from a multiple regression ($r^2 = 0.212$) of the dependent variable cutthroat density and the independent variables of pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
POOLS	0.006	0.009
CCUT	-0.019	0.133
ROADS	0.011	0.228

Appendix Table 4. Probabilities testing the null hypothesis parameter slope = 0 resulting from a multiple regression ($r^2 = 0.222$) of the dependent variable cutthroat catch/m² and the independent variables of pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
POOLS	0.003	0.009
CCUT	-0.010	0.114
ROADS	0.009	0.047

Appendix Table 5. Probabilities testing the null hypothesis parameter slope = 0 resulting from a multiple regression ($r^2 = 0.204$) of the dependent variable cutthroat biomass (g/m^2) and the independent variables of pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
POOLS	0.039	0.005
CCUT	-0.057	0.470
ROADS	0.077	0.186

Appendix Table 6. Probabilities testing the null hypothesis parameter slope = 0 resulting from logistic regression of the dependent categorical variables of high (> 0.10 fish/m²) and low (< 0.10 fish/m²) cutthroat trout density and the independent variables of pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
POOLS	0.063	0.125
CCUT	-0.055	0.804
ROADS	0.215	0.162

Appendix Table 7. Probabilities testing the null hypothesis parameter slope = 0 resulting from logistic regression of the dependent categorical variables of high ($> 0.70 \text{ g/m}^2$) and low ($< 0.70 \text{ g/m}^2$) cutthroat trout biomass and the independent variables of pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
POOLS	0.022	0.570
CCUT	0.079	0.740
ROADS	-0.070	0.681

Appendix Table 8. Probabilities testing the null hypothesis parameter slope = 0 resulting from a multiple regression ($r^2 = 0.339$) of the dependent variable cutthroat density (fish/m²) and the independent variables of the mean density of the nearest two streams (NEXT), pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
NEXT	0.459	0.009
POOLS	0.006	0.004
CCUT	-0.019	0.094
ROADS	0.015	0.042

Appendix Table 9. Probabilities testing the null hypothesis parameter slope = 0 resulting from a multiple regression ($r^2 = 0.427$) of the dependent variable cutthroat standing crop (g/m^2) and the independent variables of the mean density of the nearest two streams (NEXT), pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
NEXT	4.047	0.0004
POOLS	0.040	0.001
CCUT	-0.048	0.480
ROADS	0.104	0.043

Appendix Table 10. Probabilities testing the null hypothesis parameter slope = 0 resulting from logistic regression of the dependent categorical variables of high (> 0.10 fish/m²) and low (< 0.10 fish/m²) cutthroat trout density and the independent variables of the mean density of the nearest two streams (NEXT), pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
NEXT	10.606	0.010
POOLS	0.080	0.090
CCUT	-0.016	0.948
ROADS	0.275	0.106

Appendix Table 11. Probabilities testing the null hypothesis parameter slope = 0 resulting from logistic regression of the dependent categorical variables of high (> 0.70 g/m²) and low (< 0.70 g/m²) cutthroat trout standing stock and the independent variables of the mean density of the nearest two streams (NEXT), pool frequency (POOLS), watershed clearcut area (CCUT), and watershed road density (ROADS).

Variable	Parameter Estimate	p-value
NEXT	20.428	0.004
POOLS	0.032	0.502
CCUT	0.178	0.562
ROADS	-0.023	0.913

Appendix Table 12. Probabilities testing the null hypothesis parameter slope = 0 resulting from a multiple regression ($r^2 = 0.093$) of the dependent pool frequency and the independent variables of watershed clearcut area (CCUT), watershed road density (ROADS), watershed area (AREA), mean stream elevation (ELEV), and stream gradient (GRAD).

Variable	Parameter Estimate	p-value
CCUT	-0.391	0.672
ROADS	0.557	0.390
AREA	0.001	0.183
ELEV	0.001	0.800
GRAD	0.0005	0.974

Appendix Table 13. Mean reach width (m), total reach catch, predicted cutthroat trout reach density (fish/m²), reach cutthroat trout biomass (g/m²), and reach cutthroat trout size range for tributaries of the main Coeur d' Alene River sampled during 1994 and 1995. Reach numbering begins downstream and proceeds upstream.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
Cd'A River	1	3.4	17	0.08	1.0	76-183
	2	3.5	32	0.27	1.1	47-167
	3	2.9	26	0.13	1.5	55-195
Mosquito	1	2.5	12	0.09	0.8	44-181
	2	2.3	12	0.08	1.2	33-171
	3	1.5	28	0.40	0.9	35-112
Dahlman	1	1.9	14	0.12	0.5	42-127
	2	1.8	14	0.11	0.7	63-137
Buckskin	1	2.8	50	0.40	4.1	37-153
	2	2.2	24	0.22	4.8	38-143
	3	1.8	26	0.21	1.4	72-154
Spruce (upper)	2	2.6	38	0.42	1.0	34-137
	3	2.4	54	0.21	1.7	37-164
Marten	1	1.6	4	0.05	0.3	42-122
	2	1.3	10	0.11	0.6	69-127
	3	1.5	11	0.12	0.3	39-101

Appendix Table 13. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size range (mm)
		width (m)		density (fish/m ²)	Biomass (g/m ²)	
Deer	1	4.2	13	0.08	0.7	42-207
	2	4.3	12	0.07	0.2	42-140
	3	3.9	14	0.06	0.2	43-127
Whitetail	1	2.2	26	0.23	1.9	37-192
	2	2.3	18	0.12	1.0	35-138
	3	1.6	11	0.13	1.0	35-138
Blacktail	1	2.0	21	0.16	1.0	67-117
	2	1.5	23	0.21	1.3	56-124
	3	1.3	15	0.15	0.9	61-140
Alden	1	3.6	11	0.11	0.6	45-167
	2	2.9	12	0.07	1.0	93-160
	3	2.0	9	0.08	1.3	42-178
East Alden	1	2.6	23	0.15	0.4	37-128
	2	2.1	6	0.04	0.5	40-153
	3	1.9	14	0.10	1.1	78-178
Jordan (upper)	1	2.4	60	0.52	1.9	43-205
	2	1.8	58	0.45	1.7	43-153
	3	1.9	36	0.28	0.6	42-124
Lost Fork	1	3.2	46	0.23	0.3	51-111
	2	2.7	103	0.80	4.5	39-181
	3	1.6	25	0.22	1.7	71-161

Appendix Table 13. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
West Elk	1	3.4	10	0.06	1.0	42-254
	2	2.4	13	0.23	0.9	33-163
	3	3.0	4	0.16	1.8	35-198
Bear	1	2.1	3	0.08	0.2	31-154
	2	1.8	3	0.03	0.3	24-187
	3	0.9	2	0.01	0.4	90-175
Spion Kop	1	0.9	8	0.26	0.7	68-107
	2	0.9	1	0.04	0.2	83
Cinnamon	1	3.9	9	0.04	0.7	83-218
	2	3.7	11	0.06	0.8	69-184
Gold	1	2.0	33	0.47	1.6	32-190
	2	1.8	12	0.13	1.2	34-177
	3	2.0	34	0.36	1.7	33-164
Brett	1	2.3	15	0.05	1.0	69-236
	2	1.9	13	0.11	1.3	50-236
	3	1.8	13	0.08	0.7	40-151
Miners	1	2.7	23	0.12	1.1	42-196
	2	4.4	32	0.15	0.5	38-212
	3	2.1	36	0.31	4.0	36-186

Appendix Table 13. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
Big Hank	1	1.8	8	0.23	0.9	25-157
	2	1.9	11	0.13	1.0	35-190
	3	1.8	21	0.22	1.1	33-185
Flat	1	5.1	8	0.02	0.4	86-222
	2	5.1	66	0.12	1.0	51-204
Svee	1	3.4	10	0.04	0.8	74-188
	2	3.8	3	0.02	0.9	82-168
Teddy	1	2.0	17	0.16	1.1	40-157
	2	2.0	26	0.25	1.8	23-162
	3	2.1	35	0.29	2.5	25-168
Yellow Dog	1	3.9	13	0.06	0.6	24-225
	2	3.8	14	0.06	1.0	32-253
	3	4.0	20	0.07	1.4	43-226
Tourist	1	2.0	18	0.13	0.7	41-127
	2	1.9	23	0.26	1.3	38-156
	3	1.6	39	0.34	1.8	64-141
Downey	1	6.0	16	0.07	0.9	32-232
	2	5.0	15	0.06	1.2	41-223
	3	4.8	18	0.08	1.3	33-305

Appendix Table 13. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
North Grizzly	1	3.5	15	0.17	1.9	27-226
	2	3.7	43	0.24	2.8	24-201
	3	2.9	26	0.23	2.5	28-204
E. Fk Downey	1	3.9	23	0.12	1.3	61-178
Hemlock	1	2.9	6	0.03	0.4	64-157
	2	2.4	12	0.08	0.8	62-157
	3	2.0	27	0.15	1.7	63-180
Little Lost Fork	1	3.9	12	0.05	0.6	73-173
	2	4.3	17	0.07	0.9	69-177
	3	3.0	12	0.19	1.3	90-166
Ulm	1	2.8	11	0.07	0.8	25-183
	2	3.2	17	0.11	1.2	30-153
Sentinel	1	3.9	12	0.05	0.7	68-184
	2	3.1	14	0.07	1.2	75-183
	3	3.6	14	0.10	1.4	59-163
Clinton	1	2.6	2	0.01	0.01	45
	2	2.6	7	0.07	0.5	47-138
	3	2.7	30	0.18	1.6	38-175
Rampike	1	2.3	25	0.18	2.9	39-188
	2	3.0	21	0.26	1.5	25-177
	3	2.7	31	0.29	2.8	27-215

Appendix Table 13. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
Pine Flats	1	2.2	5	0.03	0.5	98-163
	2	2.8	10	0.10	2.6	25-196
	3	2.1	6	0.12	1.2	95-141
Cabin	1	3.4	16	0.18	0.7	37-170
	2	3.7	70	0.45	4.4	29-223
	3	2.5	55	0.42	4.2	32-183
Falls (upper)	2	4.8	40	0.17	1.3	28-165
	3	5.4	42	0.08	1.1	68-183
Haystack	1	2.1	5	0.04	0.7	119-163
	2	1.6	7	0.06	1.0	66-154
	3	1.4	3	0.03	0.6	124-149
Avery	1	1.8	22	0.17	1.3	60-129
	2	1.4	27	0.23	1.3	56-159
	3	1.3	15	0.15	0.9	61-140
Browns	1	4.0	13	0.10	0.1	32-130
	2	2.4	12	0.09	1.3	26-186
	3	2.1	16	0.12	2.4	28-202
Grizzly	1	3.9	42	0.27	1.9	21-211
	2	3.0	48	0.34	4.3	33-240
	3	2.0	28	0.27	2.1	40-198

Appendix Table 13. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
Graham	1	3.5	3	0.02	0.2	56-167
	2	1.8	11	0.05	1.4	87-280
	3	2.0	21	0.13	1.2	43-172
Coal	1	3.5	8	0.05	0.8	33-236
	2	2.9	10	0.09	1.0	68-185
Scott	1	2.0	16	0.10	0.1	31-237
	2	1.8	11	0.13	2.4	22-192
	3	1.5	27	0.30	2.2	25-166
WF Steamboat	1	5.1	28	0.14	1.4	26-271
	2	3.4	33	0.15	2.0	32-214
	3	2.3	33	0.23	2.5	24-180
EF Steamboat	1	3.5	35	0.21	1.4	29-267
	2	4.2	29	0.21	1.2	20-189
	3	2.7	30	0.26	0.3	19-207
LEF Steamboat	1	1.9	20	0.21	2.8	42-190
	2	2.3	28	0.24	2.0	37-150
	3	2.7	28	0.24	1.8	34-178
Can	1	2.9	18	0.10	1.0	53-200
	2	3.5	25	0.14	1.6	36-240
	3	3.0	10	0.06	0.8	51-181

Appendix Table 13. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
Big Bob	1	2.2	4	0.05	0.6	105-147
Barrymore	1	2.5	43	0.29	2.1	41-207
	2	2.3	23	0.17	1.7	44-187
	3	2.3	37	0.28	3.5	39-211
Indian	1	2.7	10	0.08	0.6	42-157
	2	2.5	18	0.11	1.6	31-186
	3	1.9	2	0.05	1.1	143-157
Omaha	1	1.6	56	0.47	6.3	49-215
	2	1.7	65	0.84	4.4	26-162
	3	1.1	17	0.50	1.4	29-149

Appendix Table 14. Mean reach width (m), total reach catch, predicted cutthroat trout reach density (fish/m²), reach cutthroat trout biomass (g/m²), and reach cutthroat trout size range for tributaries of the North Fork of the Coeur d' Alene River sampled during 1994 and 1995. Reach numbering begins downstream and proceeds upstream.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
Lewelling	1	2.1	1	0.005	0.2	97-194
	2	1.8	7	0.05	0.5	54-158
	3	2.4	5	0.04	0.6	99-162
Nicholas	1	2.5	5	0.02	0.2	65-151
	2	2.1	6	0.04	0.5	63-165
	3	1.7	15	0.14	1.2	64-161
Canyon Fork	1	2.1	8	0.06	0.9	56-204
	2	2.5	9	0.08	0.9	40-184
	3	3.3	13	0.06	0.5	55-188
Burnt Cabin	1	5.3	5	0.01	0.3	91-297
	2	3.7	2	0.001	0.03	97-104
	3	2.8	6	0.02	0.4	78-186
Bottom	1	1.8	5	0.03	0.2	58-168
	2	2.1	9	0.04	0.3	55-154
	3	2.3	7	0.04	0.4	64-157

Appendix Table 14. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
Lone Cabin	1	2.3	6	0.02	0.4	86-186
	2	2.1	15	0.05	0.3	35-167
	3	1.5	2	0.01	0.2	71-191
Cascade	1	3.4	10	0.03	0.3	78-224
	2	3.7	11	0.03	0.5	33-188
	3	2.6	22	0.07	1.0	46-208
Picnic	1	3.8	9	0.02	0.2	60-159
	2	2.9	12	0.03	0.3	97-147
Deception	1	3.0	6	0.03	0.3	86-135
	2	2.6	4	0.02	0.4	98-185
	3	2.3	7	0.04	0.4	68-170
Bootjack	1	3.2	1	0.004	0.1	131-198
	2	2.2	1	0.01	0.02	102
Leiberg	1	4.8	10	0.02	0.4	38-218
	2	4.3	2	0.001	0.1	186-216
	3	2.3	7	0.02	0.3	66-161
Stull	1	2.6	1	0.01	0.1	153
	2	2.7	16	0.05	0.3	57-147
	3	2.3	0	0	0	-

Appendix Table 14. Continued.

Stream name	Reach number	Mean	Catch (n)	Predicted		Size
		width (m)		density (fish/m ²)	Biomass (g/m ²)	range (mm)
Lavin	1	2.3	2	0.02	0.2	89-150
	2	2.2	25	0.12	0.6	25-194
	3	1.9	12	0.07	1.2	71-175
Hemlock	1	3.0	8	0.02	0.4	64-190
	2	3.0	8	0.02	0.3	57-183
	3	2.3	24	0.09	1.0	59-189
Tie	1	2.4	9	0.04	0.3	68-146
	2	2.6	16	0.07	0.6	52-181
	3	2.1	3	0.02	0.2	111-136
Laverne	1	3.9	8	0.04	0.5	86-209
	2	2.9	6	0.03	0.5	54-197
	3	2.8	8	0.05	0.3	44-167
Copper	1	4.3	0	0	0	-
	2	4.4	0	0	0	-
	3	3.5	16	0.07	1.4	70-230
Little Teepee	1	2.6	5	0.03	0.1	45-220
	2	2.7	1	0.01	0.1	146
	3	2.9	18	0.11	1.0	64-185
Bumblebee	1	2.9	0	0	0	-
	2	3.7	0	0	0	-
	3	2.8	5	0.02	0.2	82-173

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